

PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in or relating to Pump Actuating Devices and Liquid Pumping Systems Comprising the Same.

We, ESSO RESEARCH AND ENGINEERING COMPANY, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Elizabeth, New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
The invention relates to a pump actuating device and is particularly concerned with such a device for use in conjunction with one or more diaphragm pumps to obtain an accurate and adjustable flow of a liquid material. The invention also relates to liquid pumping systems comprising a plurality of diaphragm pumps operated by a single hydraulic displacer, and comprising one or more of such pump actuating devices controlling the flow through the diaphragm pumps. It is particularly concerned with such systems for injecting coal/oil slurries through the tuyeres of blast furnaces.
According to the invention, a pump actuating device, for use in conjunction with one or more hydraulically-operated diaphragm pumps, comprises a control chamber filled with hydraulic fluid and interposed between a hydraulic pulsation system and the diaphragm chamber or chambers of the pump or pumps, the control chamber comprising a cylinder, a piston moving in said cylinder in response to the hydraulic pulsation system and means for limiting the movement of said piston. The piston acts as a transmission element between the hydraulic fluid in the pulsation system and the hydraulic fluid in the diaphragm chamber or chambers.
The means for limiting the movement of

the piston preferably comprises a fixed stop at one end of the cylinder and an adjustable stop carried by the other end of the cylinder. The distance between the stops is adjustable, therefore, and defines the pulse volume of the diaphragm pump or pumps, which may be recorded.
Also according to the invention, movement of the piston may be used as an indication of normal operation of the diaphragm pump or pumps. Movement of the piston operates an electrical switch, repeated operation of which maintains an emergency action system in a non-operative state, while non-operation of the switch, i.e. when movement of the piston ceases, due to stoppage of diaphragm movement in the pump or pumps, brings the emergency action system into operation.
According to one embodiment of this feature of the invention, movement of a piston rod linked to the piston operates a switch in an electrical circuit which charges a condenser. The condenser discharges through a relay which renders the emergency action system inoperative. The rate of discharge of the condenser is arranged to be slow, so that repeated operation of the switch by movement of the piston rod keeps the emergency action system in the non-operative state. If movement of the piston rod ceases, however, the switch is not operated and the condenser discharges sufficiently to cause the relay to bring the emergency action system into operation.
Also according to the invention, a liquid pumping system for supplying a liquid to a plurality of feed points comprises a plurality of hydraulically operated diaphragm pumps each conveying liquid from a reservoir to one feed point, a common displacer supplying

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hydraulic pressure to all such diaphragm pumps, and one or more pump actuating devices as hereinbefore described interposed between the common displacer and the diaphragm pumps to control the volumetric throughput of the pumps.

The invention is particularly adapted to the volumetric capacity control of hydraulically-operated sleeve diaphragm pumps for the delivery of solid-in-liquid suspensions, e.g. for the injection of coal-oil or coal-water slurries through the tuyeres of blast furnaces. In such an application, it may not be necessary to employ a pump actuating device to control the throughput of each diaphragm pump supplying each tuyere but one or more pump actuating devices may be used to control total throughput of all the pumps or to control the throughput of groups of pumps supplying selected groups of tuyeres.

The invention will be illustrated by reference to the drawings accompanying the provisional specification showing particular embodiments of the invention by way of example.

Figure 1 is a diagrammatic representation of a single sleeve diaphragm pump provided with a pump actuating device according to the invention; and Figure 2 is a diagrammatic representation of a system for delivering a coal-oil slurry to the tuyeres of a blast furnace, using a number of diaphragm pumps each provided with a pump actuating device as shown in Figure 1.

Referring first to Figure 1, a slurry of known composition is fed to a sleeve diaphragm pump 1 from a pressurized feed manifold 2. The pumping action is obtained by expanding and contracting a tubular diaphragm 3 made of a suitable elastic material. This is done by applying a variable hydraulic pressure in the chamber 4 which surrounds the diaphragm 3. The actual movement of the diaphragm 3 is not defined. The delivery valve 5 of the pump is loaded with a spring 6 to obtain an opening pressure which is higher than the pressure in the feed manifold 2. The spring loading is controlled by a threaded loading adjuster 19. Instead of the spring loaded valve 5 a back pressure control valve in the delivery line of the pump could be used. Alternatively, the spring-loaded valve 5 may be dispensed with if it is so arranged that, at minimum throughput, there is an adequate pressure rise across the pump, pressure being maintained during the suction stroke by the use of a surge chamber. Isolating valves 7, 8 are provided between the pump and the feed manifold and in the delivery line of the pump, respectively, and a suction valve 27 is provided at the inlet of the pump.

The force to drive the pump is derived from a hydraulic system in which the pressure fluctuates between a value lower than

the pressure in the slurry feed manifold to a pressure in excess of the maximum pressure which can be generated under normal conditions at the pump delivery connection. The pulse frequency in this central drive system can be set at a desirable value. With it, the capacity of all connected pump units can be varied simultaneously the capacity per unit time being the product of the pulse volume and the number of pulses per unit time.

In previous systems, it is not easy to control and measure the actual membrane displacement of each individual pumping unit or the total displacement of all, or groups, of pumping units connected to the central hydraulic drive system. Also the displacement of one pump or one group of pumps can differ considerably from that of another pump or group of pumps because the individual discharge conditions are likely to vary. When all, or groups, of pumping units are connected to a displacer, it is desirable to be able to control the total flow for all, or each group, of pumping units by means of a common metering device even though the throughput of individual pumping units may be variable.

In the embodiment shown in Figure 1, a piston displacement chamber is interposed between the hydraulic pulsation manifold 9 and the hydraulic side of the pump diaphragm chamber 4.

A piston 10, which can move freely in a cylinder 11, serves as a direct link between the driving system and the pump. The stroke can be limited mechanically and as the fluids in the system are virtually incompressible the displaced slurry volume in each half cycle is the same as the volume displaced by the piston, moving in a clean hydraulic fluid.

The piston 10 is provided with a damping extension 20 at its top end, which fits into a damper 21 provided at the top end of the cylinder 11 when the piston 10 is at the top of its stroke. The damper 21 is provided with a narrow bore flow resistance 22. A fixed stop 12 is provided at the top end of the cylinder 11 within the damper 21.

An adjustable stroke limiter 13 is carried by the lower end of the cylinder 11 and is provided with a damping end 23 at its top end, which fits into a damper 24 provided on the lower end of the piston 10 when the piston 10 is at the bottom of its stroke, the damping end 23 thus providing an adjustable stop. The damper 24 is similarly provided with a flow resistance 25. A stop 26 is also provided on the lower face of the piston 10, within the damper 24.

The events during a full cycle can be described as follows:

During the period of low pressure in the hydraulic system, the diaphragm 3 is ex-

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panded by the slurry pressure, and displaces the fluid in the cylinder 11. The piston 10 is driven upwards till it rests with its end against the fixed stop 12.

5 During the period of high pressure in the hydraulic system, the fluid from this system drives the piston 10 down against the back pressure at the delivery connection of the pump 1. The downward movement of the
10 piston 10 and thus the displacement volume of the diaphragm 3 and of the slurry, is limited by the adjustable stop provided by the damping end 23. The maximum pressure in the hydraulic system is limited by a pressure
15 relief valve or other pressure controlling means and the force acting on the stroke limiter 13 is the result of the difference between this maximum hydraulic pressure and the pressure exerted by the slurry on the
20 diaphragm 3 and can therefore be limited to a practical value. Excess fluid discharged through the relief valve can be recovered on the suction stroke through a non-return valve.

25 The stroke limiter 13 can be moved by means of a threaded spindle 14 and nut 15 driven by a servomotor 16. This servomotor is connected to a position indicator (feed back) by line 17 and to a stroke limit setting by line 18. It is not obligatory,
30 however, to use a servomotor for this purpose.

With these comparatively simple means the double purpose of measuring and adjusting the displaced volume of the slurry per pressure cycle is achieved. Its functioning is not dependent on viscosity, temperature, cross section for flow and other variables as long as the piston completes its powered
40 stroke. Remote control of the displacement volume is simple. No purged instrument lines are required.

45 The actual movement of the piston 10 provides a means to signal stopping of the pumping action.

The piston movement is transmitted by a small diameter piston rod 28 passing through o-ring seals 29. A friction sleeve 30 is fitted around the rod 28 and is moved up and down
50 between fixed stops 31, 32 by friction, practically independently of the extent of the piston travel. Fixed to the sleeve 30 is a cam 33 which operates a micro switch 34 (normally open) at each passage. Each
55 movement (up and down) of the piston 10 is thus made to generate a current pulse in the primary of a transformer 35, which is connected across a battery 36, resulting in an induced EMF in the transformer secondary.

60 A condenser 37 is thus charged via a rectifier 38. The EMF across the condenser 37 causes a flow of current through a resistor 39 and a relay coil 40 in series. The circuit is electrically designed in such a way, that at
65 normal conditions the EMF across the con-

denser 37 does not drop sufficiently in the "rest" periods to let the relay contact 41 open. If, however the piston movement should stop, no more current pulses are generated and the EMF across the condenser
70 37 degenerates to a low value; the relay contact 41 then opens thus rendering an emergency circuit at 42 operative.

The embodiment of Figure 1 could easily be adapted to the control of the total volumetric throughput of two or more diaphragm pumps by connecting the chambers
75 4 of each pump in parallel to the cylinder 11.

To illustrate further the advantages of the invention, its application in a system of supply of oil-coal slurry to blast-furnace injection tuyeres will now be described with reference to Figure 2.

In this particular application it is desired to distribute a suspension of coal in oil containing a least 50% by weight of solids over a number of feed units, each capable of metering a quantity of about 100 Imperial Gallons per hour into injection tubes. These tubes project through the tuyeres into the blast furnace. The pressure in the blast furnace can range from 20 to 40 psig. It is also desired to vary the total capacity of the fuel feed from a central control position and it may also be desirable to adjust the capacity
90 of each metering unit individually. One of the safety requirements is automatic blowing out of the fuel injection tubes if the supply of fuel should stop.

The scheme in Fig. 2 shows a system in which use is made of the remotely driven and controlled hydraulic metering units described with reference to Fig. 1.

The fuel oil is moved from a tank 101 by a pump 102 into a mixer 103. A flow controller 104, located in the central control position regulates the feed rate, by means of a flowmeter 105 and a valve 106.

The powdered coal is moved from a bunker 107 into the mixer by a variable speed conveyor 108 fitted with a continuous weigher 109. This weight flow system is controlled from the central position by a flow controller 110, the set point of which is shifted in relation to the set point of the oil flow controller 104 in such a way as to obtain a given oil-coal weight ratio, by means of a ratio controller 111.

The two phases are mixed and discharged in an agitated surge vessel 112. A main feed pump 113 driven by a motor 114 transports the slurry to the metering units 115 via a ring main 116. Its delivery could be a constant volume flow. The difference between the output of the feed pump 113 and the total
120 intake of the metering units 115 is discharged back into the vessel 112 through a back pressure controller 117, acting by means of a pressure gauge 118 and a valve 119, to maintain a constant mixture pressure at the
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inlets of the metering units and a sufficient flow rate to avoid segregation in the mixture flowing through the slurry feed ring main 116.

The total flow of fuel fed into the blast furnace 120 by the metering units 115 is a main control parameter, which the metering unit capacity control system should keep constant. The capacity control of the oil-coal mixture preparation unit could follow automatically by changing the set point of the oil flow controller 104 with a level controller 121 by acting through a level indicator 122 on the vessel 112. If the level in the vessel 112 should fall, the level controller 121 will act to increase the oil flow rate into the vessel 112 and also the coal flow rate as the two controllers 104 and 110 are coupled.

The metering units 115 comprise sleeve diaphragm pumps as shown in the Fig. 1. The diaphragms are pulsated hydraulically by a main pulsator unit 123 driven by a motor 124 which varies the pressure in a fluid-filled pulsator ring main 125 cyclically. The total flow rate is the total displacement of the metering units 115 multiplied by the pulse frequency. Thus, by varying the speed of the main pulsator unit 123, the total capacity of the metering units 115 can be varied in a simple way. It is easy to do this from the central control position by means of a pulse frequency controller 126 acting through a servo speed unit 127.

The pulse volume, which each metering unit 115 can adopt, can be varied. Therefore, the total pulse volume is variable. The main pulsator 123 is designed to have a constant pulse volume which is larger than the total maximum pulse volume of all the metering units 115. Thus, during the suction period the pressure in the cylinder of the main pulsator 123 will fall abruptly when all metering units 115 are filled. Hydraulic fluid is then taken through a non-return valve 128 from the buffer tank 129. During the delivery period, the pressure in the main pulsator cylinder will abruptly rise when the metering units 115 have discharged their adopted pulse volumes. The pressure rise is controlled to a maximum limit by a back pressure controller 130, acting through a valve 131 which discharges hydraulic fluid to the tank 129. This limit should be set sufficiently high to allow all the metering units to overcome the resistance in their delivery lines.

A cross section of a metering unit 115 is shown on one unit. It shows the piston 10 in the cylinder 11, and the pump 1, with the tubular diaphragm 3 and the spring loaded delivery valve 5. The pulsations in the delivery line are in this embodiment damped out by a second diaphragm chamber 132 which is pressurised with air supplied through the ring main 133 from a source of compressed air at 142. The air pressure is con-

trolled by a controller 143 acting on a valve 144. The piston 10 can move between the top of the cylinder 11 and the stroke limiter 13. Only the stroke volume of the free piston 10 determines the stroke volume of the diaphragm 3 and the slurry delivery volume. During the low pressure part of a cycle, the pressurised slurry helps to push the piston 10 towards the cylinder top. When all the pistons have reached this position, the hydraulic pressure drops as described above and hydraulic fluid is aspirated into the main pulsator cylinder through the nonreturn valve 128. During the discharge period the hydraulic pressure squeezes the slurry through the injector tubes 134 in the tuyeres 135 into the furnace 120. Shroud air is fed to the injector tubes at 141. Injection stops when all the pistons 10 are in their lowest positions. The hydraulic pressure then rises to a set maximum as already described.

The stroke volume of the metering units 115 can be set from indicator and set controllers 136 at a central control position with a suitable servo system acting on the servo motor 16. This setting is static. It is possible simply to add up the set displacement volumes of the metering units and feed this into a total quantity and rate registering unit 137. If the total displacement volume is multiplied by the pulse repetition rate, the total rate results. This can be integrated very simply to display the total quantity of fuel fed into the blast furnace.

The piston 10 in the cylinder 11 of each of the metering units 115 is prolonged with a piston rod 28 which operates a movement alarm unit 138 on the central control panel fitted below the stroke control units 136. Should the delivery of a metering unit 115 become plugged, the piston 10 will eventually stick in the highest position, and movement will stop. The movement alarm unit 138 then gives a visible alarm for the faulty metering unit and actuates the purge air motor valve 139 of the faulty unit to blow the oil-coal mixture out of the injection line if possible. Purge air is supplied under pressure through the purge air ring main 140.

Advantages of the system shown include simple metering pump units without moving parts (drive, motors etc.), located near the injection tubes; one central metering pump driver remote from the blast furnace; simple and accurate remote control and setting of each individual metering unit; easy variation of the total fuel feed by varying the pulse frequency; no sensitive instruments in the plant; positive feed system with one feed pump remote from the blast furnace; and automatic action on failure of delivery with individual fault indication.

If individual metering of the volumetric throughput of the diaphragm pump supplying each tuyere is not required, the embodi-

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ment of Figure 2 can easily be adapted by connecting all or groups of the diaphragm pumps 1 in parallel to the cylinder or cylinders 10 of one or more volumetric capacity control devices as described in relation to Figure 1, thus providing metering of the total throughput of pumps supplying all or groups of the tuyeres.

WHAT WE CLAIM IS:—

1. A pump actuating device, for use in conjunction with one or more hydraulically operated diaphragm pumps, comprising a control chamber filled with hydraulic fluid and interposed between a hydraulic pulsation system and the diaphragm chamber or chambers of the pump or pumps, the control chamber comprising a cylinder, a piston moving in said cylinder in response to the hydraulic pulsation system and means for limiting the movement of said piston.

2. A device as claimed in claim 1 in which the means for limiting the movement of the piston comprises a fixed stop at one end of the cylinder and an adjustable stop carried by the other end of the cylinder.

3. A device as claimed in claim 1 or claim 2, in which movement of the piston operates an electrical switch, repeated operation of

which maintains an emergency action system in a non-operative state, while non-operation of the switch brings the emergency action system into operation.

4. A liquid pumping system for supplying a liquid to a plurality of feed points comprising a plurality of hydraulically operated diaphragm pumps conveying liquid from a reservoir to one feed point, a common displacer supplying hydraulic pressure to all such diaphragm pumps, and one or more pump actuating devices as claimed in any of claims 1 to 3, interposed between the common displacer and the diaphragm pumps to control the volumetric throughput of the pumps.

5. A pump actuating device substantially as hereinbefore described and illustrated in Fig. 1 of the drawings accompanying the provisional specification.

6. A liquid pumping system substantially as hereinbefore described and illustrated in Fig. 2 of the drawings accompanying the provisional specification.

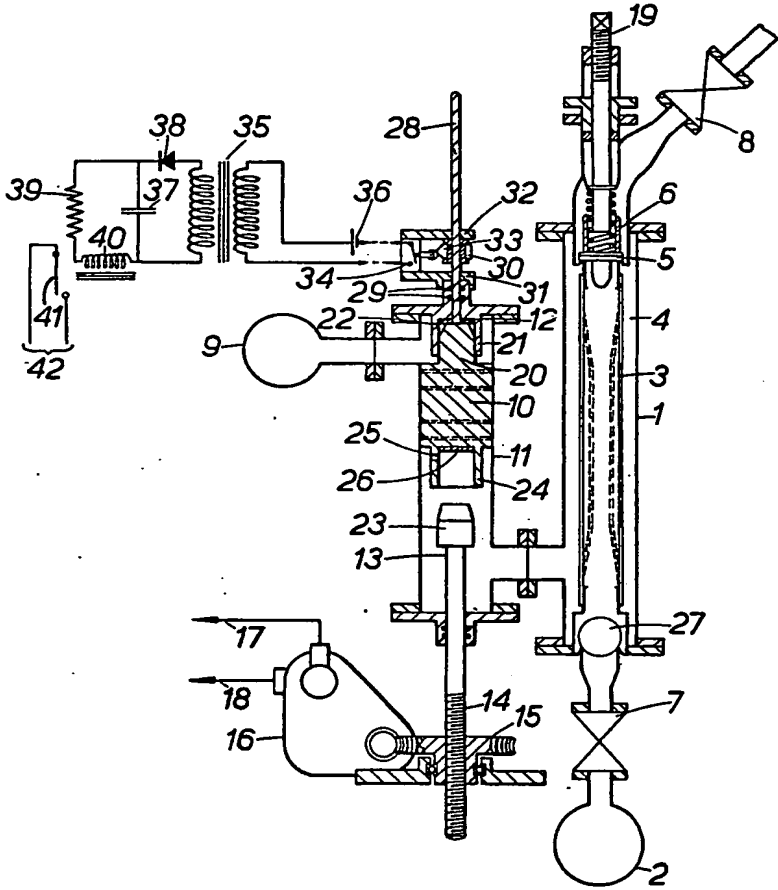
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 Sheet 1

FIG.1.



This schematic diagram illustrates the components and flow paths of a gas chromatograph. The system includes:

- Sample Introduction:** A sample inlet (109) leads through a valve (106) and a flow controller (102) into a sample chamber (107). The chamber contains a sample holder (108) and a detector (103).
- Carrier Gas Flow:** Carrier gas enters from the bottom left through a pressure-reducing valve (114), a flow controller (113), and a check valve (119) into the sample chamber.
- Detector and Signal Processing:** The detector (103) is connected to a signal processor (112) and a recorder (110). The recorder has multiple channels (117, 121) and is also connected to a power source (111).
- Gas Chromatography Column:** The effluent from the sample chamber passes through a column (115) which is housed within a temperature-controlled oven (116). The column is divided into sections (125, 133, 139) and is equipped with various valves (132, 141) and sensors (135, 140).
- Detection and Control:** The column is connected to a detector assembly (134) which includes a detector (135) and a flow controller (141). The detector is connected to a signal processor (136) and a recorder (138).

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FIG.2.

